III.2 10 kW Solid Oxide Fuel Cell Power System Commercialization

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Objectives

- Demonstrate solid oxide fuel cell (SOFC) stacks that achieve target performance, stability, and cost.
- Design and develop a SOFC system balance of plant (BOP), including air and fuel supply systems, meeting cost and reliability targets.
- Demonstrate a control system to manage the SOFC power system, including regulation of fuel and air flows and control of key system temperatures.
- Demonstrate an efficient electrical power conditioning system to convert stack output to inverter input DC voltages and regulate stack output current.

Accomplishments

- Constructed and tested a complete SOFC system satisfying the SECA Phase I targets, including an audited manufacturing cost of $742/kW.
- SOFC stacks that achieved target performance, stability, and cost were successfully demonstrated in the tested deliverable prototype.
- The Phase I cold balance of plant (cBOP), including air and fuel supply systems, was completed and successfully demonstrated to meet SECA objectives in the deliverable prototype.
- Control hardware and software providing steady-state and transient control of a SOFC system were successfully demonstrated in the deliverable prototype.
- Identified, characterized, and applied cost-effective cBOP components incorporating low cost, high volume, mass production components from industrial and automotive sources.

Introduction

Solid oxide fuel cell power systems offer the potential to generate electrical power from hydrogen or hydrocarbon fuels cleanly, quietly, and efficiently. The objective of the Cummins Power Generation-Versa Power Systems, Inc. (CPG-VPS) project is to design and develop a 3-10 kW SOFC-based power system that can be competitive with existing small diesel generating systems in terms of cost and package size, but offer significant benefits in efficiency, emissions, lower noise and vibration. Achieving these objectives requires advancement in six major areas:

1. Cell, interconnect, and SOFC stack performance and robustness including operation on low methane content reformate and tolerance to sulfur levels associated with commercially available on-highway diesel fuels.
2. Optimized manufacturing processes for production of cells, interconnects, and stack assemblies.
3. Cost-effective system and BOP design, thermal integration, and packaging of the hot components and sub-systems including stacks, fuel reformer, heat exchangers, and insulation system.
4. Reformation of ultra-low-sulfur diesel fuel to provide a reformate stream compatible with carbon-free operation of SOFC BOP and stacks.
5. Control system for regulating air and fuel flows to the stacks in proportion to electrical load and operating temperatures, and for managing stack electrical load through current regulation compatible with load sharing between the fuel cell and batteries during steady-state and transient loading.
6. Electrical power conditioning, including DC voltage boosts (converters), efficient DC power inversion to AC, and load sharing with batteries.

The team has demonstrated satisfaction of SECA Phase I objectives with progress in all areas during 2007, and has successfully completed Phase I of the SECA program.

Of particular note, the demonstrated system improved on a key SECA objective of manufacturing cost with an audited cost estimate of $742/kW, which was below the Phase I target.

Approach

The CPG-VPS approach coordinated development in a number of major areas including the development of planar solid oxide fuel cells, metallic interconnects, and stacks as well as parallel development in planar SOFC manufacturing and scale-up for economic manufacturing. Parallel work focused on development of a diesel fuel reforming system compatible with application requirements, fuel cell BOP, fuel cell and power electronics system controls, and electronic power conditioning.

Specifically, the CPG-VPS team conducted work to develop and evaluate advanced solid oxide fuel cells that provide the required performance and durability. Part of that development required conducting a progressive sequence of SOFC stack tests to validate development of materials and assembly methods for useable stacks that can achieve high fuel utilization and low degradation rates. The team integrated the BOP components, hot box subsystem, and controls into a working deliverable prototype, initiated prototype operation to shakedown the system, and successfully conducted operation of the full prototype through the SECA Phase 1 test sequence, successfully meeting or exceeding the SECA Phase 1 minimum requirements.

Results

Development work continued to improve cell performance, primarily through the development of sulfur tolerant electrodes and cells with good performance at reduced methane levels.

CPG demonstrated a high-efficiency inductor-based DC-DC boost system which was used to control current flow at constant regulated voltage to the test system load.

The team successfully completed the Phase I testing protocol to demonstrate substantial compliance with SECA Phase I minimum requirements.

TABLE 1. CPG-VPS Results Compared to Seca Phase I Minimum Requirements

	TARGET		ACTUAL	
Power Rating (Net DC @ NOC)	3 – 10	kW	3.2	kW
Cost	$800	/ kW	$742	/ kW
Efficiency Mobile (DC net / LHV)	25	%	37	%
Steady State Degradation	2.0	% / 500 hrs	1.7	% / 500 hrs
Transient Degradation	1.0	% / 10	1.1	% / 10
Total Degradation (1,500 hrs steady state + transients)	7.0	%	6.3	%
Availability	>80	%	99	%
Peak Power (Net DC)	N/A	kW	4.6	kW
Fuel Type	Comm'l	Commodity	NG	Pipeline

Conclusions and Future Directions

1. 2007 work culminated with successful completion of the SECA Phase I evaluation test including steady-state and transient evaluations and reporting results to NETL.